SOME CONSIDERATIONS RELEVANT TO THE DEFINITION OF SHARED STOCKS AND THEIR ALLOCATION BETWEEN ADJACENT ECONOMIC ZONES

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ABSTRACT

A classification of the main types of shared stocks is proposed, and a range of practical and theoretical problems associated with scientific assessment and management of shared stocks are discussed, with emphasis on defining those considerations relevant to negotiations between joint harvesters of the stock.

Some simple numerical approaches to calculations on shared stocks are outlined.

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E R R A T U M

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Please Note:

- P.31: bottom line: ..... and 2 should be roughly:

$$NF_1 \Delta t : NF_1 \frac{D_2}{D_1} (1- \Delta t) = \Delta t : \frac{D_2}{D_1} (1- \Delta t)$$

- P. 32 line 6:
.... for example, $F_1 = 0.5$, the ratio of catches in number from the same effort expended in each zone is given by 0.3 : 0.35 or roughly 46% : 54% .....

W/P8798/1

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SOME CONSIDERATIONS RELEVANT TO THE DEFINITION OF SHARED STOCKS AND THEIR ALLOCATION BETWEEN ADJACENT ECONOMIC ZONES

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INTRODUCTION

International developments in fisheries over the last few decades showed the inevitability of the concept of extended jurisdiction of coastal states as pioneered in the 1950's by the countries of South America, and as agreed to by the majority of coastal states in the form of the 1978 version of the Informal Composite Negotiating Text (ICNT) of the Draft Law of the Sea Convention. Among the most urgent factors which led to this agreement were:

a) the proven fragility of many marine resources in face of the intensive fishing pressure possible by modern industrialized fleets,

b) the relatively weak control of total fishing effort possible through most international fisheries commissions, obliged to work through a concensus among harvesting nations, each of which has its own short and long-term goals to achieve from a given fishery.

Apart from the pressing needs for new legislation and the provision of the means of enforcement, this implies (FAO, 1981) that the coastal countries now need to monitor and conserve their own natural resources. In the process of doing this, they are finding, or will find, that a significant proportion of the fishery resources they now believed were proprietory to their economic zones, are in fact shared with other coastal states, requiring a degree of mutual consultation on management (FAO, 1979).

Some of the new types of problems that this discovery leads to, could not have been given much attention in the LOS negotiations in the time available, largely because to do so would have further delayed agreement.[1/] To date there gave been few attempts to address them in the fisheries literature. Exceptions in this regard are by Hongskul (1980) on one aspect of the problem for the Southeast Asian region, and more globally, the report by Gulland (1980) who discusses in general terms the classification of shared stocks and the needs for cooperation in research between adjacent coastal states sharing common resources, as well as some of the categories of problems to be faced in managing such stocks by the several management authorities involved.

As we emerge from the euphoria of the immediate post-EEZ era, we are beginning to see more clearly that although the new Law of the Sea regime has opened up many economic opportunities for coastal states, at the same time it has placed a significant management burden on national administrations, many of which at present are ill-equipped administratively to sustain them. For example, the new regime broadens the duties of national administrations to govern access to the national "fish wealth", regulate conflicts between different components of the fleet, and ensure the ecological health and continued productivity of the resource and its environment. The difficulties for many developing countries in obtaining sound advice and practical solutions to their fisheries problems in the early years of the new regime was in fact accentuated after declaration of extended jurisdiction. Completely new problems came into existence due to the creation of maritime boundaries to the new economic zones; boundaries which are at least equal in length to the former national land boundaries,

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1/ The only clauses referring to this problem are in Article 63 of the ICNT which recommends that for stocks shared between adjacent zones, and between an EEZ and the high seas beyond, the states involved should seek directly, or through an appropriate subregional or regional organization to agree upon measures to coordinate (fishing) and conserve the stock.

and enclose a sea area in some cases equal or exceeding the former national territory. The first rather sensible approach to the problems of managing the new zone must be to focus attention first on wholly proprietary stocks, leaving shared stocks for later resolution when the 'national' stocks are under proper management. Sooner or later however, these shared resource problems will have to be tackled in conjunction with the other joint "owners" of the resource. In fact, the problem of international sharing of stocks across maritime boundaries is only a subset of the general resource sharing problem. Identical sharing problems are found between the inshore artisanal fleet and the industrial fleet fishing the same resources in the same EEZ.

This paper attempts to take a more detailed look at a limited range of the problems addressed by Gulland (1981), in particular, the problems of classification of stocks, and some of the types of calculation that will need to be addressed before and during negotiations between countries sharing a common stock. It also addresses some of the other types of measures that may be adopted by countries sharing the same stock; for example, the minimum mesh size and size limit regulations that historically preceeded the quota and effort limitation concepts. These measures still have a role to play in for example determining the effective allocation received for a certain level of effort by the participating countries, given the distribution of sizes throughout the range of the stock. It is important to stress, and is assumed implicitly throughout the paper, that the shares or allocations of the resource will be determined either directly from a TAC (Total Allowable Catch) that applies to all fishing fleets harvesting the resource, either directly in terms of a catch allocation, or by some other equivalent measure that achieves the same result (e.g. effort limitation or limited access of each fleet component to the stock), that is in line with the management philosophy of the participating countries. Some of the other indirect approaches to limiting access to a resource within a national zone are mentioned in Troadec (1981), and may be preferable to the TAC approach, which requires substantial information on the resource and its level of exploitation.

MANAGEMENT CRITERIA IN SHARED VERSUS EXCLUSIVE RESOURCES

Assuming that a population is available for capture in two or more unit areas in the course of its life history, each of which unit area is managed by a separate management authority, what, if any, is the optimal solution for the allocation problem betwen unit areas? How does this solution differ from the allocation procedure between competing national fleets for an exclusively owned stock?

Allocation problems like the above are becoming frequent in the real world, but generalized solutions are not easily arrived at. For example, a Penaeid shrimp stock, following its juvenile stages, may move from nursery areas inshore (estuaries and bays) to offshore fishing grounds, posing a problem of national allocation between artisanal fisheries inshore for juveniles, and offshore industrial fisheries. If the offshore adult component enters partially another management zone, the problem is further complicated, both in terms of defining the problem, and negotiating a solution. Still more complex situations can occur where a species moves through two or more management areas, within each of which there may be fisheries characterized by one or more gear types, each specifically suited to the predominant size range available during that phase of the life cycle. This may lead, in the extreme case to what is essentially a gauntlet fishery (Paulik and Greenough, 1966) i.e. a fishery where a species is subject to sequential risks in the course of its life history: the extreme cases being Pacific Salmon stocks and Bluefin tuna, where multiple sequential harvesting occurs at a number of different points in the life cycle.

Management criteria for an exclusively owned resource

In order to try and answer the question posed above, it will be necessary to look first at current practice in scientific management of exclusively owned stocks.

Two conceptually very different approaches to modelling yield in exploited fish populations are commonly followed in providing advice to fishery managers:

1) The analytic approach, based on known growth and mortality charac-

teristics and regular sampling for size of age composition of the catch; leading to an estimate of the yield obtainable from each recruit entering the fishery for a given level of fishing mortality (F) exerted. Together with estimates of the annual recruitment of young individuals to the fishable population, this allows the potential annual yield for a given level of fishing mortality to be estimated; and in particular, the change in fishing mortality rate that would be required in order to attain F_{MAX}: the fishing intensity corresponding to the Maximum Yield per Recruit (fig. 1a).

2) Direct monitoring of the commercial yields obtained from a population as a result of past levels of fishing effort may eventually form the basis for an empirical description of the population's response to different intensities of fishing. This description may be formalized by fitting a production model, which is a statistical description of how the equilibrium of long-term average yield has varied in the past with changes in fishing effort exerted. Most significantly, the fishery may be referenced to the point of Maximum Sustainable Yield (MSY), which corresponds to a level of fishing effort of f_{MSY} (fig. 1b).

These two approaches to defining possible management options may be used independently or in conjunction depending on available information sources. Potentially at least, the first approach offers a more flexible and accurate means of calculating the effects of fishing intensity, and in addition allows effects of changes in size at first capture (e.g. the impact of mesh size regulations) to be calculated (fig. 1c)

In the following section we will consider first the yield per recruit approach to management, and how it is affected in the case of shared resources, and in the subsequent section will be examining the simplest case of a production model which takes into account the effects of sharing or competition for a common resource.

Consider first the case of an exploited stock at the level of fishing mortality (F_{MAX}) that yields the maximum yield/recruit of species A at a given size l_A at first capture. There was theoretically no difficulty in selecting this fishing mortality rate and size at first capture as the optimal ones in order to maximize the overall yield per recruit (Y/R) from the population, when joint access, and a common management regime existed. In fact, yield per recruit criteria were, and still are among the key criteria

used by fisheries commissions for deciding on management measures. For stocks remaining wholly within an EEZ, we usually recognize now that the fishing mortality F_{MAX} yielding the maximum yield per recruit is a less than optimal criterion for estimating amount of fishing to be exerted and that socio-economic factors should now be given more weight than in "high seas" fisheries. It is therefore more usual now to employ criteria such as the $F_{0.1}$ concept (fig. 1a) which are considered to approximate more closely to economic optima for the fishery as a whole. Although the yield at $F_{0.1}$ is slightly less than maximal, it is taken with a significantly lower fishing effort (i.e. more economically), and maintains the stock biomass high enough for major fluctuations in stock size to be reduced compared with the fishing effort equivalent to F_{MAX}. The level of fishing mortality $F_{0.1}$ is defined as the point where the tangent A-B touches the yield per recruit curve (fig. 1a). (Line A-B is parallel to a line C-D drawn through the origin, with a slope which is 1/10 of the initial rate of increase in yield per recruit with F).

Whatever the criterion of optimality used when the stock is under single management, we now recognize that for a situation where two or more management authorities are separately managing parts of a common stock in adjacent EEZ's, the possibility of either attaining the long-term optimal yield per recruit, the maximum recruitment level, or even the optimal total yield, in the face of uncoordinated exploitation by the other party, is rather remote, particularly if resource harvesting strategies differ. Needless to say, where a single agreed-to optimum yielding the largest joint sustained yield from the stock can be attained by cooperative action on a shared stock, it is still the best stratagem to aim for. This agreed-to objective may however be difficult or impossible to achieve if each country is required to remain within its EEZ boundary during harvesting, since even migratory species are rarely homogenous in size and local abundance throughout this range. Thus, under these circumstances, at least one of the parties may be obliged to take the resource at a size and fishing intensity that will not allow the overall optimum to be attained.

Obviously economic or political considerations extrinsic to fishing have to be considered, that make shared access, or a common fishing zone, infeasible. However, this possibility should be examined carefully first, together with the associated problems of defining common regulations, rules for access, and national shares, since common access to the resource

may in many cases be the only way of maximizing the yield. Other options that achieve the same objective may also be considered: for example, offering an exclusive harvesting franchise with free access to a company owned jointly by both parties.

There may also be problems in defining common economic criteria that make $F_{0.1}$ impossible as a joint management objective. Whether or not common access to the whole range of the stock is agreed to, it will be necessary in an agreement on shared stocks to define national objectives, and recognize that these are not always compatible. Thus, one country (or in the case of allocations within one EEZ, one fleet), may be intent on optimizing rent from the resource with the minimum fleet size, while the other country (or fleet) may wish to maximize employment in coastal communities. Alternatively, one party may prefer for reasons of consumer preference, to harvest at a smaller size than that favoured by the other country. Usually these conflicting strategies will be expressed by a steady rise in combined fishing effort before one or both parties recognize that the situation merits negotiation. Unfortunately, as in other spheres of existence, the recognition of conflicting interests does not make an agreement to negotiate a foregone conclusion; particularly for the party that believes it is benefiting most (or losing the least) from the current situation.

Before discussing types of stocks and different criteria for sharing, it would seem worthwhile therefore, to consider the question of unrestrained fisheries competition. This problem is defined in the following section in the simplest case possible, namely for 2 fleets (whether operating in the same zone, or different zones), in the absence of any agreement on allocations for harvesting.

Competition without allocation: a simple production modelling approach to shared stocks

What will be the effect of competition for a single resource by two national fleets exploiting the same stock without a fisheries agreement? From a simple extension of the logistic theory of population growth we can see that at least 2 cases may be postulated:

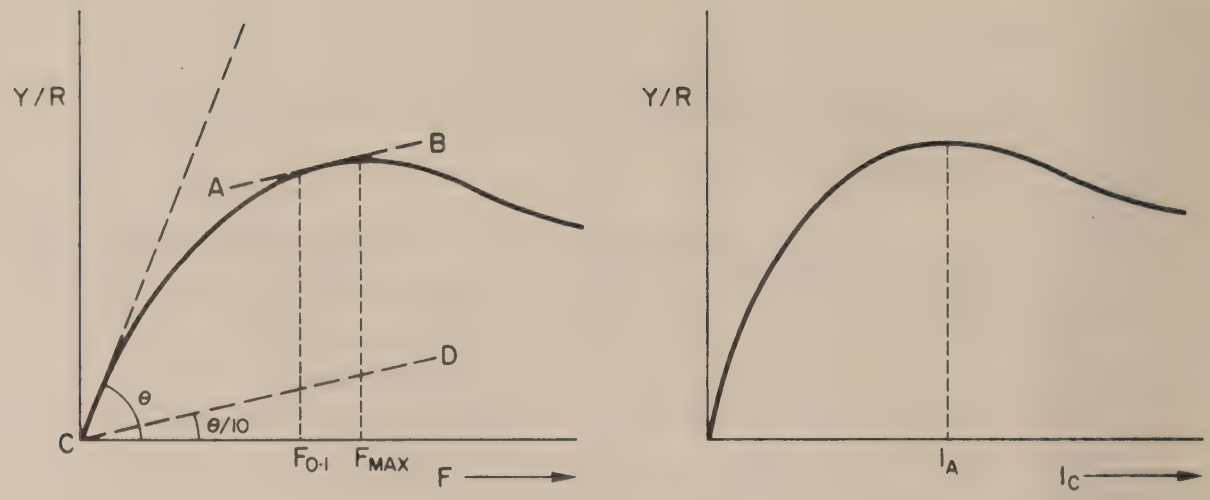

Figure 1. Diagrammatic representation of a change in yield per recruit (Y/R) with a) fishing mortality F showing method of calculating $F_{0.1}$ point, and b) with size at first capture l_c for a given F, showing size l_A giving maximum yield per recruit.

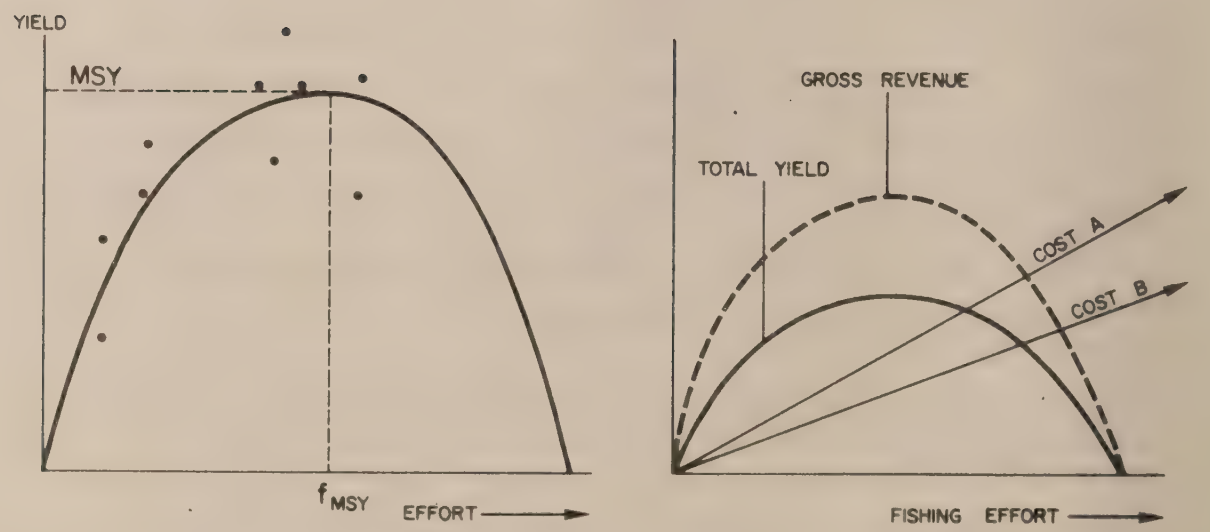

Figure 2. a) illustrating production curve fitted to historical data on annual yield and effort for a single management unit
b) overall yield in weight and in revenue as functions of effort for two separate fleets A and B sharing a common resource but with different costs of fishing.

- one where agreement is mutually beneficial;
- the other where its benefits are largely one-sided and where in unrestricted competition benefits may be expected to accrue to one participant in the fishery.

Consider first the situation which prevails in the absence of regulation of the level of effort by the fishing fleets of two different nations, fishing exclusively a common resource with no other entrants.

First assume a common unit of fishing effort, expressed in terms of one fleet, so that in the simplest case of two homogeneous fleets, the effort of fleet (B) is given in terms of effort units for the other fleet (A), taken as a standard and calibrated in terms of the relative catch rates (U_A and U_b) when both are fishing together on the same resource (Figure 3).

Thus, if $U_B = BU_A$, then f_B units of nominal effort for fleet B equals a fishing effort of Bf_B units of fleet A (and we will consider the effort of fleet B from now on to be given in units of fleet A).

Assume now that the yield model can be approximated by a simple logistic so that $Y_T = a f_t - b f^2_t = Y_A + Y_B$.

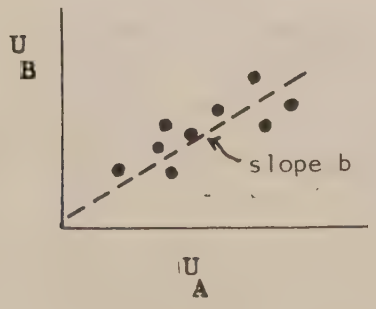

Figure 3. Cross-calibration of effort units from two fleets in terms of their respective mean catch rates on the same grounds in the same season.

Also assume that prices per unit weight landed P_A and P_B are constant (but not necessarily equal), and independent of local abundance (this would be approximately true for example where prices paid are controlled by a world market for which total supply greatly exceeded production from the particular fishery in question). We may now express revenue for fleets A + B as:

$$R_A = P_A Y_A; \qquad R_B = P_B Y_B$$

Since yield to A (in common effort units) would be a simple fraction of the total effort exerted,

$$Y_A = (af_t - bf^2_t)\,(f_A/(f_A + f_B))$$

and similarly for Y_B,

Now consider the net revenue to fleet A , taking into account the costs C_A where:

$$C_A = A_A + B_A f_A$$

i.e. costs are made a simple linear function of effort.

Then the net income or rent from the resource Q is given by:

INCOME = REVENUE - COSTS

$$Q = R - C$$

when $$R_A = P_A\,(af_t - bf^2_t)\left[\frac{f_A}{f_A + f_B}\right]$$

hence $$Q_A = P_A\,(af_t - bf^2_t)\left[\frac{f_A}{f_A + f_B}\right] - A_A - B_A f_A$$

and $$Q_B = P_B\,(af_t - bf^2_t)\left[\frac{f_B}{f_A + f_B}\right] - A_B - B_B f_B$$

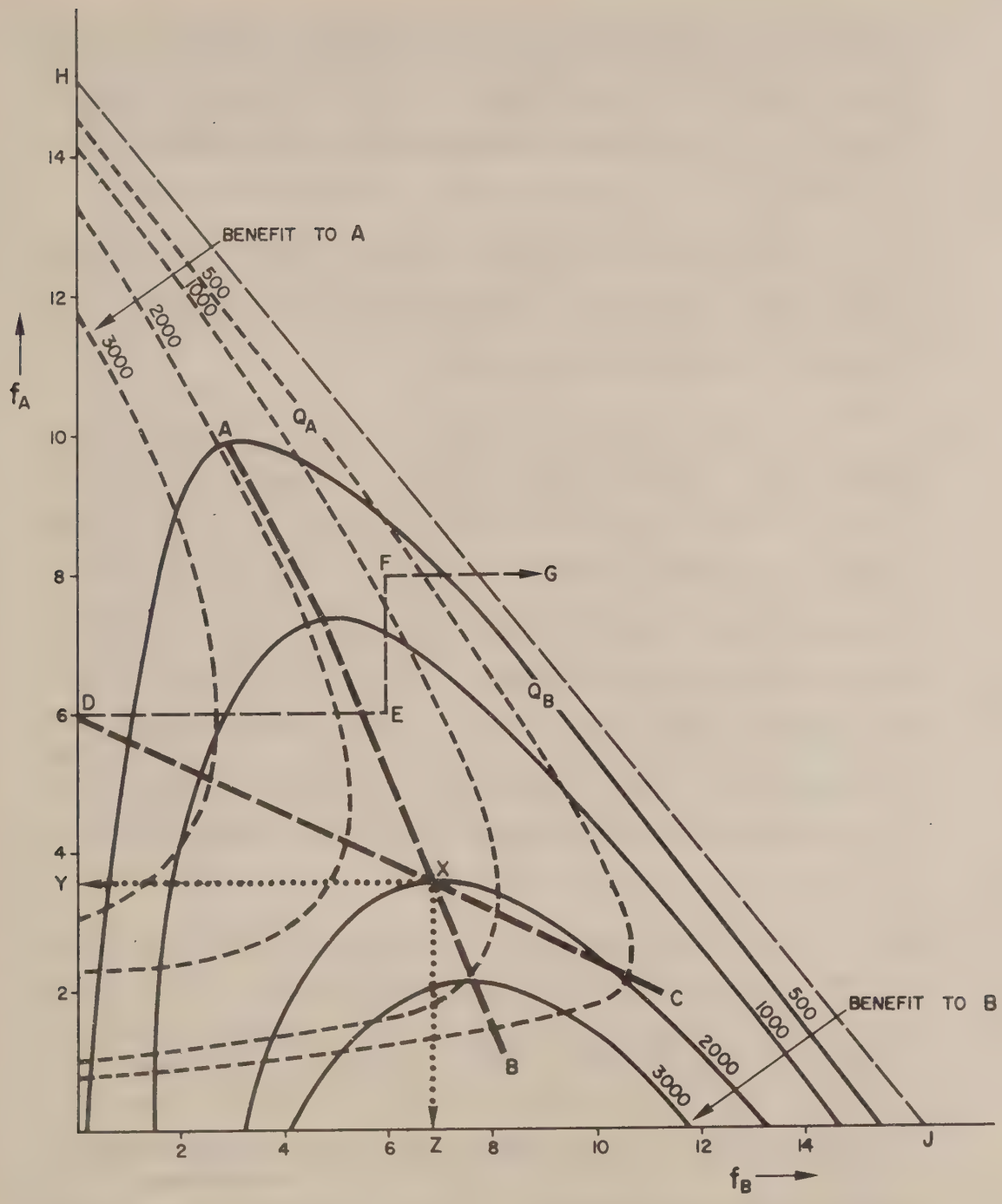

Figure 4. Benefits to two fleets sharing a common stock under conditions of fishing effort by country A + B such that $f_A + f_B = f_t$ is the total effort exerted on the stock (see text for explanation).

$Q_A + Q_B = Q_T$ may then be calculated for a series of given values of f_t and different proportions of effort expended by the two fleets A + B within this total effort limit. A typical result of this type of calculation is shown in Figure 4. (A program for calculating benefits for other parameter sets is given in Appendix I).

The two sets of curved lines, one for each country, each join those points where the same benefits occur to one country as the fishing effort of both countries change. The following account illustrates how this diagram may be interpreted in practice.

The line DX represents the trajectory of levels of effort for fleet A which gives it the most benefits given some particular level of effort of fleet B. Now, let us assume that fleet B enters at point D a fishery formerly completely dominated by fleet A, and increases its effort to roughly 7 units. In order to obtain the most benefits during the unilateral increase in effort of fleet B, fleet A would have to decrease its effort from 6 to less than 4 units (i.e. following line D-X), and in any case suffering an eventual drop in benefits from over 3000 units to roughly 1500 units, while benefits to fleet B increase to almost 2000 units. At point X it is clear that fleet B has a marginal advantage in benefits, but in any case, at point X, both fleets will suffer a drop in yield from any unilateral increase in effort.

Consider now trajectory D→E resulting from unilateral increase in effort of fleet B while fleet A effort remains constant. Fleet A's benefits are eroded from (say) 3500 units (583 benefits per unit effort) to 1500 units (250 benefits per unit effort or BPUE's), at point E. At the same time, benefits to fleet B reached (say) 1400 units, or 230 BPUE's. If now fleet A increases effort to 8 units in response to this intrusion, its benefits at point F drop to just under 1000 units, or roughly 100 BPUE's, while that of fleet B synchronously drops to 750 units, or roughly 120 BPUE's. Clearly further increases in effort (eg by fleet B to point G) continue to erode benefits to both parties. This illustrates, albeit in a rather theoretical fashion, the fact that fisheries agreements based on good understanding of the resource are to the benefit of both parties, while unrestricted competition results in economic loss to all participants.

We can see that the dashed lines A - B and C - D indicate the effort levels for each country that provides it with the greatest benefit for any

given effort level exerted by the other. Where these two dashed lines cross, at point X, there would be no benefit in either country increasing its fishery effort independently of the other. In fact, if combined fishing effort of the 2 fleets exceeds a given level (represented by line H-J), under the logistic model, benefits to both fleets would of course be negative. In this sense, X represents an optimal situation, although there is no indication that this point is necessarily more stable than any other one, or that this point will necessarily correspond to either the maximum yield or maximum benefit. One may however hazard a guess that in the long run, if the parameters of the model remained stable (in itself not very likely) the relative effort level exerted by each fleet would oscillate around a ratio of f_Y: f_Z (Fig.4) corresponding to the effort ratio at X. This may therefore be regarded as one possible criterion for deciding on national allocations. John Pope (pers.com.) notes that under some circumstances, where one fleet greatly dominates the resource, it is possible for lines A - B and D - C not to cross; in which case, there is no practical way in which the weaker participant can influence the fishing strategy of the other party. We may envisage that this situation corresponds to (for example) the situation when species X is a small component of the by-catch in zone A, but is abundant, and the principal species sought in zone B. In general however, there is rarely any benefit to uncontrolled increases in effort. Even if fleet A succeeds in replacing fleet B by economic competition, it is then usually vulnerable to an even greater loss in net benefit because of its higher investment, if a new fleet B now enters the fishery on a more economically efficient footing, or because the new strategy of B is (for example) to increase employment, protein supply or foreign currency earnings, irrespective of immediate economic benefits. In other words, rarely does unrestrained competition benefit either party in the long run.

FACTORS RELEVANT TO NEGOTIATIONS ON SHARED RESOURCES

It is clear that if there are basic grounds for agreement in a fisheries negotiation, any mutually agreed considerations or terms can be included in the agreement, not all of which need to be in the field of fisheries, nor mentioned explicitly in the agreement arrived at. On the other hand, if we for the moment confine ourselves, perhaps rather unrealistically, to those factors having a particular bearing on the fishery in question and avoid questions of 'linkage', we may discriminate between relevant and irrelevant factors by the following definition:

"Relevant factors in any negotiation on common resources are those that come into play to influence the national shares from the common resource in absence of a negotiated agreement".

As will be noted later, such a criterion is particularly useful in reducing the factors that need to be considered to a manageable number.

EFFECTS OF LIMITATION OF ACCESS

Later on in this article we go on to consider some of the factors which could result in an inbuilt inequality of access to one of two management authorities, and we may conclude that the principal factor that could lead to such an inequality must result from differences in ease of access to the resource at a point in time or space when it is particularly vulnerable to harvesting. Although differences in gear used could initially lead to such inequalities, from experience it is evident that such advantages are usually transient, since presumably the other party could adapt the same new methods of harvesting if they are effective in their EEZ. Equally, it is probably spurious to argue strictly from the point of view of the present comparative cost effectiveness of different fleets. Although economic considerations play a key role in deciding on investment within an economic zone, the existing level of investment in the fisheries sector of two countries sharing a common resource is less than convincing as the only criterion for a long-term negotiation on sharing the resource, since economic factors may themselves differ as a result of differing economic priorities within the two or more countries concerned. For example, the distant water vessels that dominated many large oceanic resources in pre-EEZ days were probably less efficient in overall economic performance than smaller coastal fleets would have been if operating in the same economic milieu. Despite this, distant water fleets possibly would have continued to dominate the most productive coastal resources in the absence of EEZ's, simply because the factors dictating their operation were not solely those available to simple economic analysis within a common free market economy, but reflect the economic and other objectives of the country of origin, and not those of the owner of the EEZ.

Returning to our scenario of two or more competing management authorities harvesting a common resource without a fishing agreement, we may conclude with Gulland (1981) that the factor governing their relative

shares may begin to be defined by first carrying out a simple geographic classification of the resource along the lines presented in the next section. In order to do this, a map (or better, a series of maps of the resource, one for each season or month), should be prepared showing the distribution of the resource and its landings in relation to the EEZ boundaries or proposed boundaries. One example of this type of basic source document is given in Hare 1977. The FAO Atlas of the Living Resources of the Seas (1981) gives more extensive but less detailed examples of distribution patterns. These maps, together with information on the species biology, should then allow the classification of each resource along the lines discussed in the next section.

CATEGORIES OF RESOURCES WITHIN NATIONAL ZONES AND BEYOND

A consideration of the principles that might be used in allocation of renewable fishery resources between EEZ's (or between national EEZ's and the high seas beyond[1/]) prompts one to consider five types of resources that may be broadly categorized as follows:

Category I: Stocks that lie almost entirely within a single national jurisdiction.

Category II: Non-migratory resources[2/] lying across the boundary between adjacent zones, and which are continuously available in each zone.

1/ In some circumstances in the argument that follows, the high seas beyond national jurisdiction will be regarded as a special type of economic zone, not in other respects substantially different from other EEZ's except that exclusive national ownership does not apply here.

2/ Here we follow the restricted definition of migration "as a directed and seasonally timed movement of a given stock or life history component of a stock between two well defined regions." (Dynamic pool mixing or random dispersal processes are not considered here to be migrations, even though the distances moved by individual fish may be considerable).

Category III: Migratory species moving across boundary areas which are only available in each zone on a seasonal basis.

Category IV: High seas stocks that are only occasionally or partially available inside national zones.

A further group, Category V, which will not be considered further here, contains those high seas stocks which occur exclusively outside EEZ's. (This is rather a theoretical category, since nearly all 'high seas' resources (e.g. whales, tuna) spend some time inside EEZ's during their life history).

Table 1 illustrates in a general sense the types of resources and sub-categories which can be considered under the main headings above. Some practical examples of a number of these categories are given in FAO (1973). It can be readily seen that the classification (although convenient) cannot be the only one possible. For example, if high seas areas are considered as a special type of economic zone, then Categories I and V are synonymous, and Category IV stocks can be reassigned to either Category II or III, depending on the behaviour of the resource.

Alternatively, some significant sub-groupings emerge, distinguished by lower case letters, that may or may not be important, depending on the nature of the allocation process.

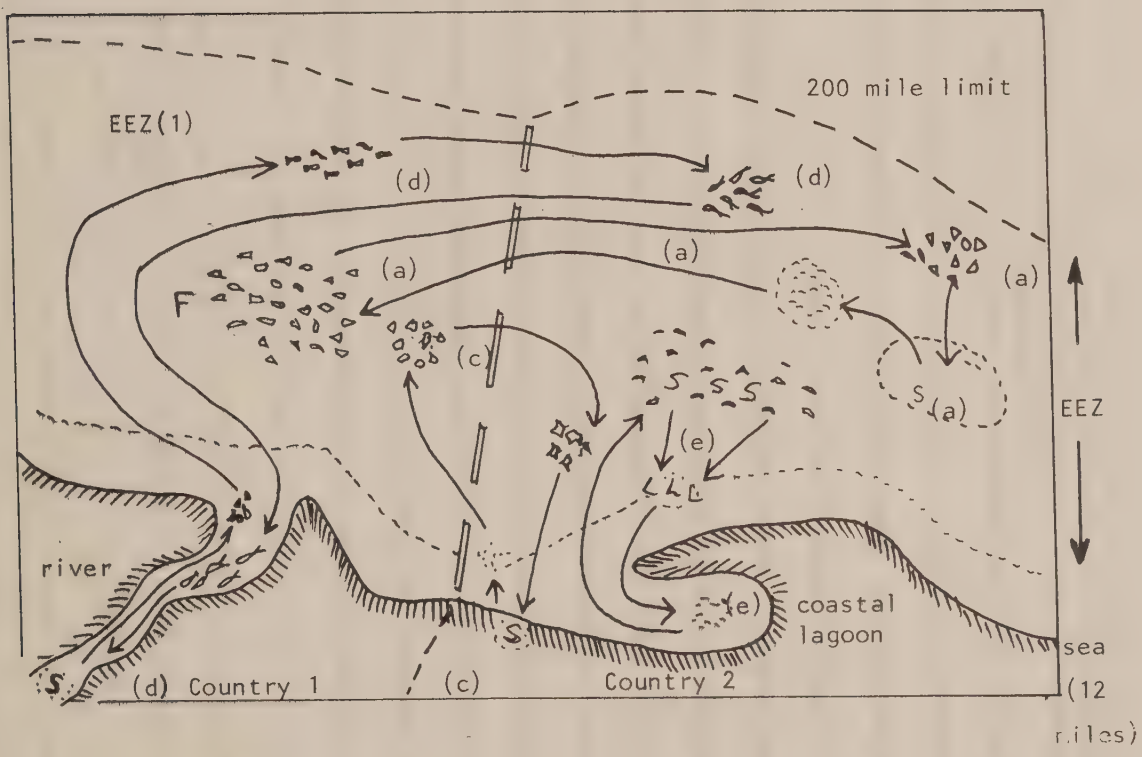

Figure 5. Diagrammatic representation of types of migratory stocks moving between zones (see Table 1)

Key

S = Spawning area

F = Feeding area

(a) to (d) refer to sub-categories of stocks III (a) to III (d) in Table 1.

Table 1

Some useful Sub-Categories of Stocks in Relation to EEZ's

Main Category	Sub-Categories
I. Stocks confined to one EEZ	Those coastal renewable resources, whether pelagic, demersal or anadromous fish, shellfish, or marine plants, that remain largely within the territorial sea. These include: a) Those resources of the EEZ which are largely sedentary during the exploited stage (e.g. octopus, scallops, oysters, conchs and certain non-migratory crabs and shrimp species), even though reproduction may be by 'random' dispersal of free-swimming larvae in the sea; in some cases, carrying larvae from one EEZ to another. (One may include here also certain fish stocks with territorial habit, such as reef-dwelling fish). b) Pelagic and demersal fish resources of the offshore banks and basins which move around within the EEZ, but have no clearly defined areas of spawning, (e.g. some Anchoveta stocks). c) A broad and diverse category of stocks spawning, or rearing their young within well-defined localized areas of the EEZ, the territorial sea, or connecting coastal or inland waters of the country in question, but spending the rest of their life history occupying different or larger areas of the same EEZ

Table 1 (continuation)

Main Category	Sub-Categories
II. Non-migratory stocks lying across boundary of adjacent zones	Sub-categories II (b and c) are identical with those of I (b and c) except that an EEZ boundary lies across the stock distribution.
III. Migratory stocks moving between zones seasonally	This category (equivalent to category I (c) stocks, but whose migratory range is crossed by a maritime boundary), includes many important stocks of demersal and pelagic fish (e.g. gadoids, clupeids) where migration between separate spawning and feeding areas occurs on a seasonal basis. Four sub-categories may usefully be distinguished: a) Species spawning within well defined areas of one EEZ (such as some clupeids, hake, squids and cuttlefish), but ranging widely through two or more EEZ's as adults. b) Species breeding in or above the littoral zone (e.g. capelin, marine turtles, seals), on the open sea coast, but which have a high seas distribution, or occupy two or more EEZ's as adults. c) Anadromous species spawning in estuaries and rivers (e.g. salmon, shad), but which are fully marine as adults, or those spawning in coastal lagoons

Table 1 (continuation)

Main Category	Sub-Categories
	and marshes (e.g. mullets) but where the adults are fully marine and in both cases may have a high seas distribution in 2 or more EEZ's.
	d) Those species (e.g. many penaeid shrimps in coastal lagoons and rock lobsters on fringing coastal reefs) that, although free-spawning at sea, have specific and localized coastal nursery areas for post-larval growth, although they move offshore again as adults.
IV. High seas stocks occasionally available in national EEZ's and V. Purely high seas stocks	These rather similar categories (containing, e.g. tunas, whales) present common problems to the world community, and the basis for allocation is also rather similar in most cases. They are not dealt with in detail here, but category IV allocations follow the same principles defined later for category III, except that the ownership of the high seas component is less well defined at present.

TYPES OF CRITERIA USEFUL FOR DECIDING ON ALLOCATIONS OF RESOURCES BETWEEN EEZ's

Negotiations on the boundaries of adjacent EEZ's and/or in dividing up the renewable resources of the (formerly common) zone, have usually been based on a number of factors, of which ownership of the fisheries resource or the fishing rights in the area is only one type of consideration. We will only be concerned here however, with technical aspects of the allocation problem; taking the existing marine boundaries as given. In what follows we consider which types of criteria out of the large number theoretically possible, should be given weight in deciding on the appropriate national allocation to each country, given that the maritime boundaries are already in place. It is fully recognized however that the information allowing practical application of these criteria will not always be available, nor will it always be easy to generalize upon the appropriate weightings to be given to each type of criterion.

LESS TANGIBLE RESOURCES OF EEZ's

Before decribing in more detail the criteria which are presently used in determining allocations, it would be useful to look first at some potential criteria that might be considered to be relevant to the way in which the shared fish resources of two or more EEZ's are allocated by EEZ.

Table 2 outlines some of the 'issues' that may be considered to have a bearing on the allocation of a common resource between two or more EEZ's.

Table 2

Types of Criteria that may be used in Assessing Allocations from Shared Stocks

Historical criteria	Criteria of current socio-economic importance	Bio-oceanographic and long-term criteria
1) Shares of the total yield are in proportion to the national landings from the stock in question over the past n years by each country	1) Allocations are made a function of existing fleet size and current investment in fish plants and other infrastructure (i.e. current capital investment), in the fishery.	1) Spawning areas (partly or wholly) located within one EEZ may be used as a justification for a larger share of the resource
2) National allocations take into account the past history of responsible management measures and the existence of national legislation aimed at conserving the stocks for all participants	2) The allocation process takes into account their socio-economic effects, particularly the impact on employment in coastal communities, especially where there is a traditional dependence on these resources for basic nutritional requirements.	2) Feeding areas (partly or wholly) located within one EEZ may be used as a justification for a larger share of the resources
3) Other economic opportunities that may have been, or are being sacrified in order to conserve the stock are taken into account in the allocation process		3) Areas of high primary or secondary (e.g. areas of upwelling, marshes, estuaries), or of forage fish of importance to regional productivity lying within one EEZ are used as a justification for a larger share of the common resource feeding on them

Table 2 (continuation)

Historical criteria	Criteria of current socio-economic importance	Bio-oceanographic and long-term criteria
	4) The value of current investment in conserving and protecting stock size is taken into account	4) Suitable areas for fishing which occur within one EEZ allow for a greater effective share
	5) Other economic opportunities that are still being foregone in order to preserve the fishery are taken into account	5) Stocks migrating seasonally into a given EEZ, or shared between EEZ's are more available/profitable to the fishery in one EEZ at the appropriate size, age and condition for human consumption, than the other(s) thus allowing a greater share
		6) The range of sizes and ages of capture available in each EEZ are closer or further from the economic or market optima

MANAGEMENT OF MIGRATORY SHARED STOCKS

Gauntlet models (Paulik and Greenough, 1966) consider the problem of sharing a common migratory stock when fishing occurs in turn in different areas and different times in the life history, as the stock passes in sequence through a series of separate fisheries, in each of which the risk of death from fishing accumulates.[1/] One example of this is Sardinella in West Africa: captured as juveniles in beach seines, it is then caught by small purse seines from canoes and locally-based medium sized seiners, then by midwater (foreign) trawlers offshore (Troadec, pers.comm.). Illustrating this with a hypothetical example, suppose that species x migrates through zones A, B and C, in each of which it is commercially available at mean sizes $\bar{l}_A$, $\bar{l}_B$, $\bar{l}_C$ (Fig. 6). Now let us suppose that our conventional yield/recruit unit stock calculations predict that the "maximum" yield per recruit will occur at mean size of first fishing $\bar{l}_F$, where $\bar{l}_A < \bar{l}_B \leq \bar{l}_F < \bar{l}_C$. One might then suggest that fishing should be confined to zones B and C in order to maximize the yield/recruit. At the very least, yield should be partitioned between zones B and C, to the exclusion of A. This, needless to say, will not sit well with the management authorities for zone A, who may be denied access to zones B + C. In fact the authorities for zone A may act to reduce the number of young individuals recruiting to zones B and C by exerting uncontrolled effort on the 'juvenile' stages before they reach a size providing the optimal yield (Fig.7). On the other hand, if fishing opportunities or stock availability are greatest in zones B and C, their authorities also may act to monopolize the total allocation, if only by denying access in their zones to fishermen from A. This unrestricted competition can lead to the situation, where (if we assume that size at maturity $\bar{l}_M \geq \bar{l}_B$), the authorities in zone C, although receiving only the few fish lucky enough to escape through A and B, may while seeking to maintain their allocation, drive the

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1/ "Running the gauntlet": Terminology from medieval English, referring to a courtly ceremony in which a knight runs between two rows of his fellows, each of which strikes at him with a mailed glove (gauntlet) attempting to prevent him from completing the course.

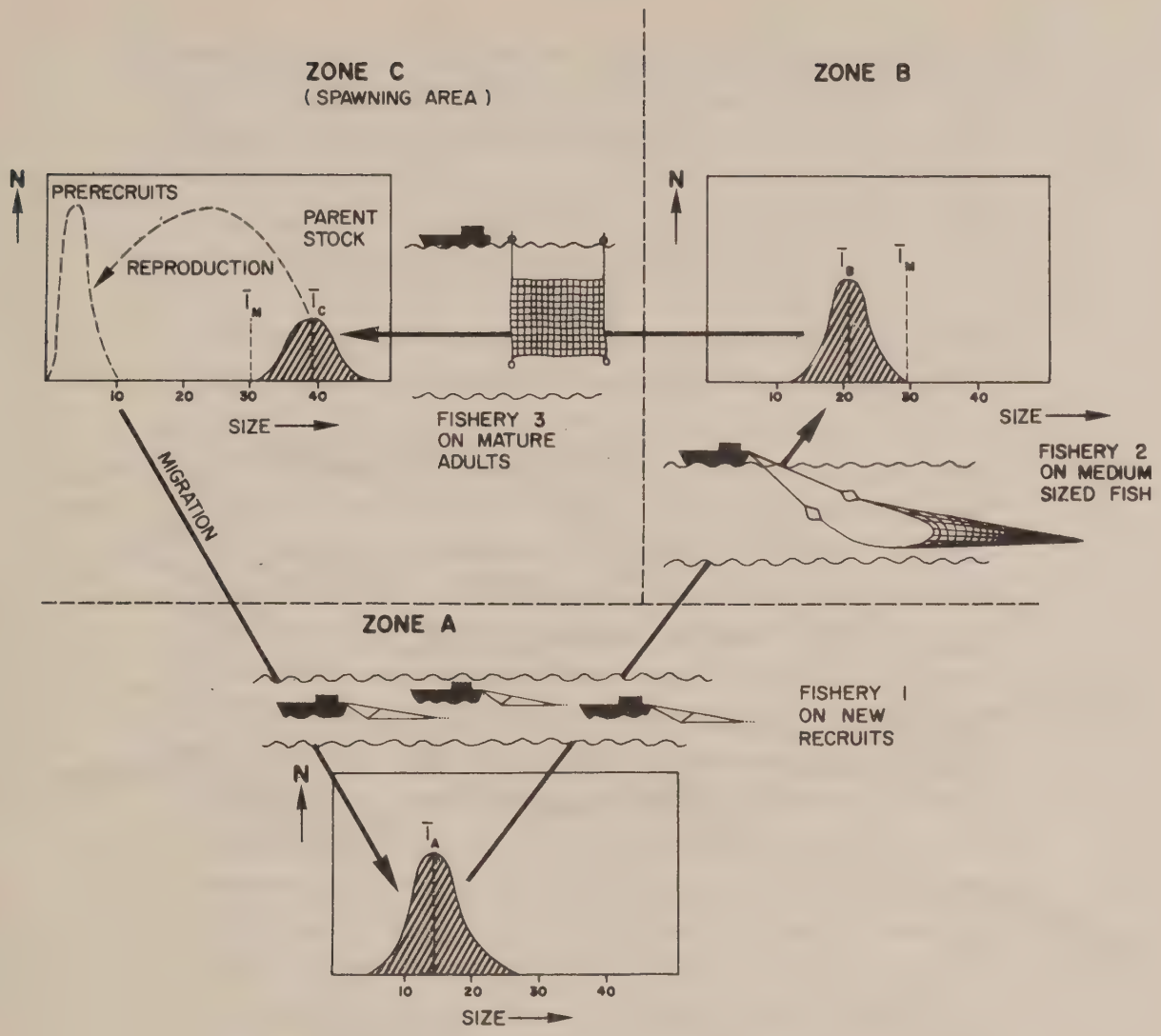

Figure 6 Illustration of a simple gauntlet model, in which a species spawned in zone C, first reaches fishable size in Zone A, before passing at successively larger sizes through successive fisheries (and hence running an accumulating risk of capture in Zones B and C later in its life history)

(l_A, l_B + l_C are mean sizes of capture, and l_M mean size at maturity).

Note: Pre-recruits in Zone C are too small for fishing

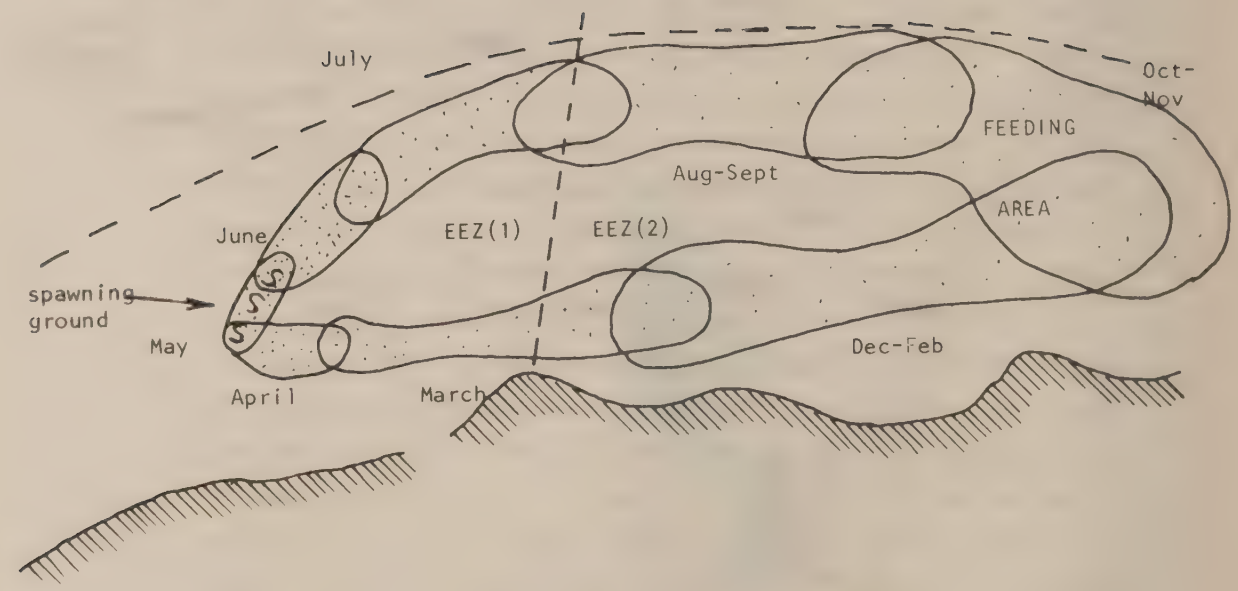

Figure 7 Seasonal migration of a hypothetical (Category III) stock between spawning and feeding areas in two zones (outlined areas illustrate seasonal extents of distribution).

spawning stock size to a very low level. This may even lead to a decline (in sequence) of fisheries in zone C, and in fisheries A and B in subsequent years as recruitment falls off.

The grounds are obviously set for some form of conservation assuring mutual benefits. This may take two forms:

1. The best (but politically least likely strategy), is to pursue the original goal of a commonly agreed level of sustainable yield or benefits. The only way to achieve this may be for authorities A and B to prohibit directed fishing for species in their zones, with the assurance from authority C of an allocation within their waters. The only example where this has actually occurred is in the Pacific fur seal fishery, where it has been taken to a point, such that agencies A (Japan and Canada) agreed to halt wasteful at-sea harvesting where many individuals killed were lost to the harvesting vessels, in return for a share in the product (harvested efficiently on shore by agencies B (Russia and the U.S.A. -Alaska); the net proceeds of harvest then being shared (after subtracting costs of agency B) by all parties. This approach appears to merit serious consideration for other stocks, particularly for those (previously unharvested) resources where neither sharing party has a history of dependence or harvesting of this particular product. Here a jointly commissioned fishing company with fixed terms of reference and access, may be a feasible approach, with benefits in proportion to national investment and/or stocks fished. In addition to the reduced costs of monitoring harvesting, this approach may also facilitate coordinated marketing of this product domestically, or to third parties.

2. The second option (which necessarily abandons the concept of the highest yield attainable) presupposes problems with managing effort by zone, or problems of regulating access to each other's zones. Here, if agreement can be reached on the catch allocation to each party, using methods described in the section on "allocation criteria", then these proportions can be the programming criterion for a solution that permits the joint management authority to aim for:
$Y_{SUBOPT} = Y_A + Y_B + Y_C$ where $100\ Y_A/Y_{SUBOPT}$ = the

percentage allocation for zone A, B (and etc.), agreed upon by negotiation. This goal is readily formulated by a simple simulation using the catch equation (if growth and mortality parameters are known) for mean recruitment level R, where fishing in each zone is treated as a single gear with its own size selectivity and, partial selection factors. In the simulation, overall fishing effort is then varied to obtain the largest Y_{SUBOPT}, subject to the restraint that Y_A, Y_B, and Y_C are in the pre-agreed ratios.

A method of allocation that is a subset of that described immediately above, may be employed if no other objective criterion can be found for an allocation. If the growth and mortality characteristics of the population are known, the allocations may be preset in the ratio of the numbers or biomass that would have been initally available in each zone if the population were an unfished one.

CRITERIA FOR DETERMINING THE NATIONAL ALLOCATION FROM A SHARED STOCK

A good qualitative review of some of the factors to be taken into account by a management authority in approaching the question of joint management is given in Gulland (1981). The next sections consider:

1. the kinds of calculations that can be envisaged in approaching the hard questions of negotiating national allocations from a common stock, and
2. examines in a critical fashion some of the less easily quantified criteria that have been proposed for partitioning stocks, particularly on the basis of the generalized "biological productivity" of each zone.

JOINT MANAGEMENT AND ALLOCATION CRITERIA FOR NON-MIGRATORY SHARED STOCKS

For shared stocks in category IIb (local and non-migratory stocks) the problems of joint management will depend on whether the resource is sedentary (even if movement of larvae and juveniles between zones occurs), or if the resource is mobile and some kind of

'dynamic pool' (i.e. mixing of individuals throughout the range) applies.

Sedentary stocks

In the first case, where at least the adult of the species are relatively sedentary or very local in their movements (e.g. most molluscs, and some crustacea and fish), we may conclude that although cooperative action is still desireable, separate management with only limited consultation may be possible in each EEZ, even if the 'stock'[1/] lies across EEZ boundaries. There is still the possibility that an extremely reduced biomass due to fishing in one zone will affect spawning success of the whole; but here there is often the likelihood that refugia (areas with locally unfavourable fishing conditions, due to depth, distance from shore, rough seas or rough bottom, etc.) will normally exist that may protect at least part of the mature resource from exploitation. These refugia (or unfished stock components) may even be created by local legislation to close areas (e.g. marine parks) or by closure of the fishery during seasons of high vulnerability of key life history stages. We may note however that the effectiveness of this biologically rather attractive type of mechanism is often difficult to establish by scientific investigation, although preceding the modern industrial era, seasonal or area closures formed the basis for many traditional methods of fishery regulation.

Dynamic pool stocks

In the case of 'dynamic pool' stocks, we may also have a situation where individual management is possible if the authorities in question each adopt similar measures, or where the predominant part of the stock is in one zone. It is clear, however, that this type of stock which mixes continuously across a boundary (and hence is not strictly migratory in our sense) may still be seriously overfished in

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1/ The definition of a unit stock in these cases may be difficult, especially if wide larval dispersion between local adult concentrations is the case.

its habitat as a whole by heavy fishery in only one of the EEZ's if substantial interchange occurs, or if better fishing opportunities exist in one zone: (see next section on migratory stocks, where similar considerations apply). The benefits of joint action will also apply here, and in the simplest case the allocation should be in the ratio of the standing stock in each zone, or in the ratio of the product of mean density and area of the stock in each zone.

FISHING OPPORTUNITIES IN EACH ZONE FOR A SHARED STOCK

For the non-migratory but motile stocks described above, which may disperse across boundaries of EEZ's, there may be factors other than abundance which will affect the relative catch which may be taken economically by existing fishing technologies in each zone in the absence of mutual access.

The presence or absence of fishing grounds is the most obvious one of these: groundfish on a rocky shelf area may be effectively invulnerable to fishing by bottom trawl, or if fishing is by longline, feeding behaviour may differentially affect the seasonal catchability of stocks which occur in a particular zone at a given stage of its feeding/breeding cycle. The availability to capture by mid-water trawl or purse seine may also depend on degree of dispersal or schooling of the stock at each stage of its migration, or its depth range during that stage.

Migratory stocks

Figure 7 illustrates in diagrammatic form a rather common situation, where the geographical range of a migratory stock is partitioned by the boundary between two EEZ's. The stock spends the greater part of the autumn, winter and early spring on the fishing grounds in EEZ (2) before passing the spring and summer in EEZ (1) where spawning occurs. A first practical approach to the question of allocation would be to prepare a series of monthly/seasonal maps of the distribution of the species, and ascertain the proportion of the stock area falling in each EEZ for each time period considered using for example a planimeter to estimate these stock areas.

Looking at the question of allocation, one might superficially decide that relative allocations to EEZ (1) and EEZ (2) should be in the ratio of the proportion of time the stock spent in each respective zone; thus the allocation to EEZ (2) would roughly be 8 months = 67%; EEZ (1) getting the remaining 33%.

There are major qualifiers to this approach however which make it seem less than ideal for a migratory species, particularly when our earlier axiom is borne in mind. For example, the presence of the stock in zone (2) for two-third of the year will not necessarily confer a major advantage on the fishermen of zone 2. Apart from any possible seasonal effects of weather which may affect the efficiency of operation in each zone, the efficiency of operation with trawl or purse seine is a direct function of fish or school density, thus the mortality resulting from application of one unit of fishing effort, (and hence the resultant yield) is a direct function of density. Adopting Baranov's 'area swept' formulation, $f = qf = (\frac{ca}{A})\ f$, is the case of (e.g.) trawl fisheries, where $\underline{c}$ is the proportion retained, $\underline{a}$ is the area swept by the gear during one unit of effort, and $\underline{A}$ is the total extent of the stock at the time of fishing, we note that that for a given stock size N, occurring at two seasons in different areas A_1 and A_2, and hence at different densities $D_1 = N/A_1$ and $D_2 = N/A_2$, the relative fishing mortalities resulting from the same fishing effort are given by:

$$F_1 : F_2 = \frac{Ncaf}{A_1} : \frac{Ncaf}{A_2} = D_1 : D_2$$

i.e. the fishing mortality exerted by one unit of effort is given by the ratio of the densities of the stock (if this is the only factor determining catchability, which may not of course be the case, since q may also differ in the two zones). Assuming however, a simple case, where q is constant, the effect of differing density or availability in the two zones may be taken roughly into account in the following section.

Thus, if F_1, the annual fishing mortality rate in zone 1 is known, F_2 is given by $F_1.D_2/D_1$, then the ratio of catches by number in zones 1 and 2 should be roughly in the ratio:

$$NF_1\,\Delta t : NF_1\,\frac{D_2}{D_1}\,(1-\Delta t) = \Delta t : \frac{D_2}{D_1}\,(1-\Delta t)$$

where Δt is the proportion of time spent in zone 1, and $1 - \Delta t$ the remainder of the year the stock spends in zone 2. This is the ratio of numbers caught assuming the same effort and constant catchability in the two zones, the same size at capture and an equal possibility of natural death in the two time intervals. If $D_1 = 2D_2$, and $\Delta t = 0.3$, (roughly the situation in fig. 7), then if for example, $F_I = 0.5$, the ratio of catches in number from the same effort expended in each zone is given by: ~~0.139~~ 0.3 : ~~0.161~~ 0.35 or roughly 46% : 54% in zones 1 and 2 respectively. This contrasts with the ratio 30% : 70% based solely on residence time, and although this may not form an ideal basis for a long-term relative allocation from the stock, it obviously comes closer to representing the relative harvest for a given expenditure of fishing effort in the two zones, bearing in mind that it may of course be modified if zoogeographical factors, or the development of new methods of fishing change the effective availability of the species in each of the EEZ's entered during its life cycle and migration.

BIO-OCEANOGRAPHIC CRITERIA AND THE ALLOCATION PROCESS

Here we make reference to Table 2, where several qualitative but very important considerations arise, namely the question of spawning and feeding areas. It is unlikely that so simple a division will occur with respect to areas of feeding as in our example in Figure 7, but quite often areas of spawning may be very restricted, even for extremely large stocks. In these cases (e.g. categories IIIa, b and c in Table 1), the management authority for the EEZ containing the spawning area has a special responsibility for maintaining the spawning zone for the common stock in a productive condition, as well as some excellent opportunities to take a major portion of the yield at high densities for a relatively low expenditure in effort. One may also see in the simplistic example given here, that if the management authority of zone 1 were to take all responsible measures to protect the spawning stock from over-fishing during this period of high vulnerability, (such as, for example, by exercising a limited harvest, or instituting a seasonally closed area covering the spawning grounds), there would be additional costs involved in managing this fishery, which would not be equally shared by

authority 2. This situation becomes more exaggerated for coastally spawning stocks, and for stocks, with coastal nursery areas (categories IIIb, c and d), where in addition to the costs of management, conflicting alternative usage of the area for industrial use (pollution), shipping, agriculture (run-off of pesticides), swamp drainage and recreational usage must also be considered. These factors can lead to a real cost being assumed by management authority 1) in order to protect the resource.

This, of course, reaches its apogee for anadromous stocks, where in addition to the above factors, hydro-electric projects, and agricultural irrigation works are also in competition for usage of the national waterways. This may necessitate substantial capital investment to protect the resource, and in some cases, may even require provision of hatchery facilities to ensure that the 'run' is maintained. Under these circumstances, it may not be unreasonable for the management authority concerned to request the right to harvest a large part of the yield. Referring again to our axiom earlier, this management authority would presumably be able to seriously affect the state of the stock in absence of an agreement or joint fishery regulation, arguing again for a significant share of the resource.

There may be other factors however which although rather nebulous and difficult to quantify without existing knowledge of biological oceanography, have been considered on occasions to play an important role in the allocation of shared stocks. These may be looked at for convenience under two headings, but are essentially interrelated.

1. Biological productivity of the two EEZ's

It should be remembered that the greater part of the ocean's surface is biologically low in productivity because of the very low concentration of the nutrients needed to support the marine food chain. Supplies of nutrients in surface waters come principally from upwelling (e.g. Cushing 1969), either due to 1) a wind-driven water mass meeting a coastline, 2) at the boundaries of water masses of different characteristics, or from coastal sources such as estuarine runoff from rivers, nutrient-rich water from coastal lagoons, or in

the form of detritus feeding directly into food chains from mangrove swamps, coastal seaweed beds and marshes (e.g. Martin et al. eds. 1981). These major localized sources of productivity are unevenly distributed along the world's coastlines, and in one sense constitute a major 'environmental resource' for the EEZ that contains them.[1/]

It may however be difficult, if not impossible, to quantify the contribution of these productive zones to the growth and biomass of those commercial species (migratory or otherwise) that depend on them for part or all of their nutrition, given that natural dispersal of marine productivity in space and time means that the originally restricted source of primary (plant) production is dispersed by currents or active migration of the food web components that depend on it for their food. Attempting to argue for a larger allocation on the grounds that the primary production it is based on originated in your zone, is in some ways rather analogous to claiming a share of neighbouring countries fresh water resources because the rainfall that produced it originated from evaporation from your national zone. Here again, our principle can be applied: if it is not practical for you to harvest all the marine productivity originating in your zone (or prevent it from leaving your zone), it is not practical to demand a 100% share in negotiation.

We may note that for many migratory species, the seasonal cycle of migration may take them between one geographical area (e.g. an upwelling zone) where feeding and biomass growth is largely carried out, to rather distant locations where for example spawning occurs, and then possibly on to other areas where larval and juvenile development occurs. All such areas being essential to the development of such a species, it is impossible to assign a relative importance to each. Examples where spawning and feeding areas are geographically separate are many herring and tuna stocks.

1/ We may note however that the exact location of areas of fish stocks or high production are not entirely fixed: the world's largest single fishery, the anchoveta fishery off Peru collapsed in the early 1970's and the major area of anchoveta production appears now to have shifted to the south.

In the example given in Figure 2 however, we may see that the waters of management authority 2) provided a major proportion of the biomass increment or forage to the stock in question. In this case, although it is hard to quantify this factor, its effect may be considered to counteract (although to a largely unquantifiable extent) the negotiation advantages of management area 1) resulting from the location of spawning areas in their zone. From the point of view of our practical principle however, management authority 2) would only be able to gain leverage from this factor if it could be shown that their harvesting of the forage fish in zone 2 fed upon by the common stock in question, would seriously affect yields from it in zone 1, which seem unlikely to be the case.

2. Species interactions

The other aspects that are worth serious consideration relate to the question of potential interactions between a migratory species and those endemic stocks which are important commercially, and occupy the economic zone for the entire duration of the life history (i.e. category 1 stocks), but compete with the migratory stock for food.

Because the biological productivity of the zone is limited at the base by geographic and physical oceanographic factors, the seasonal intrusion of a migratory element can lead to a wide variety of interactions, many of which are difficult to quantify at this time, for example:

a) Seasonal intrusion of high level predators may result in a consumption of significant fractions of the biomass of important type I stocks. (It has been estimated that fish consumption by large pelagic fish and marine mammals in some local situations eg. the Bering Sea, may equal or even exceed that harvested by man). Is the 'preventative' culling of these predatory populations to low levels by the fishermen in one EEZ going to conflict with their direct commercial utilization by fishermen in another?

b) Competition for food between for example local and migratory small pelagic fish (e.g. mackerel) may have negative effects at high density of migrants, on a wholly localized resource (herring) (Lett and Kohler, 1976). This may take the form of competition for food during the juvenile and adult phases, or as predation by the migratory stocks on the juvenile stages of more important higher level local type I stocks such as cod. Negotiations on the allocations for the transient migratory species theoretically should take account of their impact on wholly proprietary stocks, but again we can resolve this question by asking what control each management authority could exert on its share of migratory fish in absence of an agreement.

c) On the other hand, the presence of these migratory stocks may provide food for higher level predators, or act as attractants for even higher order migratory predators such as tuna.

In summary, it is very difficult to see how these types of biological considerations can be taken into account in deciding on allocations, since it is already clear that there will be occasions when the target species for management may seriously differ between adjacent EEZ's, depending on the relative economic importance and biological role of the individual resources in each zone. Again, the hard truth of the matter is that the bottom line in any agreement is likely to be determined by the ability of each management authority to affect the situation in its own favour in absence of agreement, even though such an approach is likely to be less favourable to all parties than a negotiated agreement.

CONCLUSION

A number of diverse factors could be taken into account in considering relative allocations for EEZ's sharing common stocks, and it is evident that these may become more clearly defined as our knowledge of the fisheries systems and their productivity improves. One may consider that the division into three types of considerations mentioned in Table 2 is unnecessarily complicated, and that only historical and current factors of economic importance should be

addressed in looking at the allocation between EEZ's. Criteria based on current levels of investment may well be the only ones available in some cases, and as such would have to be given an appropriate weight. They do however depend on the nature of past and present economic infrastructures and demographic considerations. These may not be the ones to ultimately prevail in the long-term, so that they may be the basis for an interim agreement, but are unlikely to be fully satisfactory in the long run. The final category of considerations in Table 2, which considers the life cycle and distribution of the resources, and the contribution of each EEZ to the well-being of the stock and its most efficient harvesting, may be in the long run of equal or even greater import, especially if a clear competitive advantage goes hand in hand with other more fundamental factors, such as the possession of the spawning area within the EEZ of one party.[1/] However, as we begin to discover more about the complexities of, and interactions of stocks with each other and the environment they occupy, we must bear in mind that the EEZ's and their boundaries are, from the point of view of many of the resources themselves, meaningless abstractions. The rigid application of territorial prerogatives for migratory stocks, will only work to the mutual disadvantage of all parties. Conversely, a mutually beneficial pattern of fishing can only result from cooperative management and mutual restraint by all concerned. In many situations we must conclude that some controlled mutual access to each others national zones may be a necessary precondition for efficient harvesting.

1/ Interim agreements taking into account the existing relative investment by two countries in a shared resource may for example be allowed to run over the expected half life of existing plant, perhaps arranged on an ascending or descending basis, until a final allocation decided on a more fundamental basis is reached (unless periodic review of allocations is agreed to anyway).

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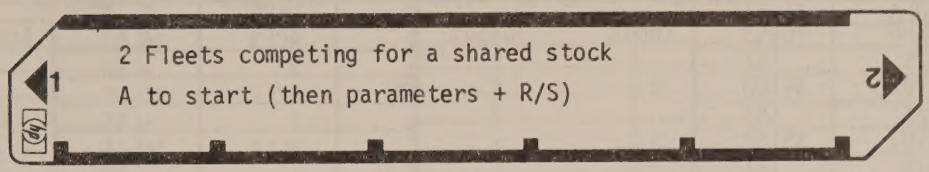
User Instructions



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Set calculator to RUN and Norm and			
	Read card. Push A to start:		A	
2	Begin input data by enter parameter value +			
	push R/S each entry:			
		a	Param R/S	
		b	" R/S	
		P_A	" R/S	
		P_B	" R/S	
		A_A	" R/S	
		A_B	" R/S	
		B_A	" R/S	
		B_B	" R/S	
		f_A	" R/S	
		f_B	" R/S	
3	Calculator prints out values for:			f_T
				f_A
				Q_A
				f_B
				Q_B
				Q_T
				$\%Q_T$ (A)
	The value of f_B is then incremented by 2 units			
	and the calculation repeated successively for			
	the same f_A until a key is depressed to stop the			
	calculator		Any Key	

STEP	KEY ENTRY	KEY CODE	COMMENTS Input	COMMENTS Output
001	* LBLA	21 11		
	CLRG	16-53		
	R/S	51		
	STO0	35 00	a	
	R/S	51		
	STO1	35 01	b	
	R/S	51		
	STO2	35 02	P_A	
	R/S	51		
010	STO3	35 03	P_B	
	R/S	51		
	STO4	35 04	A_A	
	R/S	51		
	STO5	35 05	A_B	
	R/S	51		
	STO6	35 06	B_A	
	R/S	51		
	STO7	35 07	B_B	
	R/S	51		
020	STO8	35 08	f_A	
	R/S	51		
	STO9	35 09	f_B	
	R/S	51		
	* LBLB	21 12		
	RCL8	36 08		
	RCL9	36 09		
	+	- 55		
	STOA	35 11		
	PRIX	- 14		F_t
030	RCLA	36 11		
	X^2	53		
	RCL1	36 01		
	X	- 35		
	CHS	- 22		
	STOB	35 12		
	RCL0	36 00		
	RCLA	36 11		
	X	- 35		
	RCLB	36 12		
040	+	- 55		
	STOB	35 12		
	RCL8	36 08		
	PRIX	- 14		F_A
	X	- 35		
	RCLA	36 11		
	÷	- 24		
	RCL2	36 02		
	X	- 35		
	RCL4	36 04		
050	-	- 45		
	RCL6	36 06		
	RCL8	36 08		
	X	- 35		
	-	- 45		
	PRTX	- 14		Q_A
	STOC	35 13		

STEP	KEY ENTRY	KEY CODE	COMMENTS Input	COMMENTS Output
	RCLB	36 12		
	RCL3	36 03		
	X	- 35		
060	RCL9	36 09		
	X	- 35		
	RCLA	36 11		
	÷	- 24		
	RCL5	36 05		
	-	- 45		
	RCL7	36 07		
	RCL9	36 09		
	PRTX	- 14		f_B
	X	- 35		
070	-	- 45		
	PRTX	- 14		Q_B
	RCLC	36 13		
	+	- 55		
	PRTX	- 14		Q_T
	LSTX	16-63		
	X⇄Y	- 41		
	÷	- 24		
	1	01		
	0	00		
080	0	00		
	X	- 35		
	PRTX	- 14		Q_A(% Q_T)
	SPC	16-11		
	RCL9	36 09		
	2	02		
	+	- 55		
	STO9	35 09		
	GTOB	22 12		
	RTN	24		
090	R/S	51		
100				
110				

REGISTERS

0	1	2	3	4	5	6	7	8	9
a	b	P_A	P_B	A_A	A_B	B_A	B_B	f_A	f_B
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Program Listing

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
				170			
20							
				180			
30							
				190			
40							
				200			
50							
				210			
60							
				220			

LABELS				
	B	C	D	E
	b	c	d	e
	1	2	3	4
	6	7	8	9

FLAGS
0
1
2
3

SET STATUS		
FLAGS	TRIG	DISP
ON OFF 0 ☐ ☐ 1 ☐ ☐ 2 ☐ ☐ 3 ☐ ☐	DEG ☐ GRAD ☐ RAD ☐	FIX ☐ SCI ☐ ENG ☐ n____

Program Description

Program Title Competing fleets for a shared stock

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Program Description, Equations, Variables, etc. Assuming the logistic model for production from a resource shared by two fleets or countries, a common unit of effort preadjusted for both, a constant price per unit weight landed, and costs a linear function of effort defined separately for each fleet, then the net incomes or rents from the common resource to fleets A and B are given by:

Q = REVENUE (R) - COSTS (C)

$$Q_A = P_A (af_t - bf^2_t) \left[\frac{f_A}{f_A + f_B}\right] - \left[A_A - B_A f_A\right] \qquad (\text{if } R_A \geq C_A)$$

and

$$Q_B = P_B (af_t - bf^2_t) \left[\frac{f_B}{f_A + f_B}\right] - \left[A_B - B_B f_B\right] \qquad (\text{if } R_B \geq C_B)$$

allowing Q_A and Q_B to be calculated for a series of values of f_t (total effort) partitioned into efforts of fleet A (f_A) and B (f_B) respectively.

Key:

P_A = Price per unit weight landed (fleet A)

P_B = " " " " " (" B)

A_A, B_A = simple linear function parameters describing cost fishing (fleet A)

A_B, B_B = simple linear function parameters describing cost fishing (fleet B)

a, b = parameters of logistic model fitted for whole stock (total effort f_T as abscissa; total landings $(af_t - bf^2_t)$ as ordinate)

NB. Plotting values of $Q_A + Q_B$ or $\left[\frac{Q_A}{Q_A + Q_B}\right]$ x 100% for the range of non-negative values, using f_A and f_B as axes will show readily the relative advantages to the two fleets of a given effort input.

Operating Limits and Warnings Negative values for $Q_A + Q_B$ will of course result from various combinations of parameters. Testing the apparent values by hand may be a useful preliminary to full-scale calculation.

DO NOT USE THIS SPACE